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14. ABSTRACT
To augment and expand the capacity of our robotics program, Adams State University purchased equipment specifically for undergraduate research and as well as classroom use that coincides with DoD research interests such as artificial intelligence and computer science. The acquisition of TETRIX robotics, Clearpath Robotics Husky mobile robot platforms and NAO Next Gen humanoid robots support the efforts of Adams State's STEM faculty to develop a full-fledged robotics laboratory that will transform the university's research capacity and potential to engage students in STEM studies. The acquired 3D printing systems as well as the CNC milling

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Report Title

Final Report: Robotics Laboratory to Enhance the STEM Research Experience

ABSTRACT

To augment and expand the capacity of our robotics program, Adams State University purchased equipment specifically for undergraduate research and as well as classroom use that coincides with DoD research interests such as artificial intelligence and computer science. The acquisition of TETRIX robotics, Clearpath Robotics Husky mobile robot platforms and NAO Next Gen humanoid robots support the efforts of Adams State's STEM faculty to develop a full-fledged robotics laboratory that will transform the university's research capacity and potential to engage students in STEM studies. The acquired 3D printing systems as well as the CNC milling machine and CNC lathe will enable students to learn valuable 21st-century skills that have direct application in the working world and facilitate robotics research far beyond the department's existing capabilities.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

None

Patents Awarded

Awards

None.

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

None.

Final Report - W911NF-14-1-0068
Robotics Laboratory to Enhance the STEM Research Experience
PI – Dr. Matt Nehring

I. Introduction

Our original proposal consisted of heavy overlap between undergraduate education and undergraduate research – specifically, most of the equipment served dual roles. At the time of submission we had four faculty involved in the project as collaborators: Dr. Matt Nehring (physics); Professor George Sellman (computer science); Professor Ankur Chattopadhyay (computer science); and Dr. Matthew Iklé (mathematics). Each individual was the lead for a smaller project within the larger grant. The four projects are listed here with the lead individual noted with underline:

A. **Project #1: Search-and-Rescue** (Collaborators: Dr. Matt Nehring, Physics; Professor George Sellman, Computer Science; and Professor Ankur Chattopadhyay, Computer Science)

B. **Project #2: NAO Humanoid Robot** (Collaborators: Dr. Matthew Iklé, Mathematics, and Professor George Sellman, Computer Science)

C. **Project #3: Visual Anonymity in Video Surveillance** (Collaborators: Professor Ankur Chattopadhyay, Computer Science; Professor George Sellman, Computer Science; and Dr. Matt Nehring, Physics)

D. **Project #4: Colorado Robot Challenge** (Collaborators: Professor George Sellman, Computer Science; and Dr. Matt Nehring, Physics)

Special Circumstances:
Between the time we submitted our proposal and when we obtained quotes for the NAO robots, the price for these systems was cut nearly in half. Given the rapidly changing landscape in this field and the increased competition between different companies, we submitted a request to re-budget the savings to purchase an additional NAO system and two additional humanoids from the company ROBOKIND. This request was approved.

As of May 1, 2014 we understood that Professor Ankur Chattopadhyay would not be returning to Adams State University in August. Project #3 was very heavily reliant on his expertise in the field of surveillance and was not an area that we could continue the proposed research or project. As a result, we submitted a re-budgeting request to refocus the funds originally allocated to that project to Project #4 instead. This re-budgeting request was approved.

Section II below summarizes the equipment purchased using grant funds and Section III briefly describes research efforts for each project listed above.

II. Purchased Equipment - W911NF-14-1-0068

Equipment/Project Description & Items	Manufacturer	Qty	Cost
UGV Mobile Research Platforms		**Project Total**	**$66,118**
Husky A200 UGV Mobile Research Platforms Open IMU system integrated with Husky SICK LMS Outdoor LIDAR Outdoor PTZ Camera NovAtel GPS mobile unit	Clearpath Robotics	2	$66,118
Humanoid Robot Systems		**Project Total**	**$80,492**
NAO Humanoid Robots	Aldebaran	6	$52,114
Choregraphe Software (site license)	Aldebaran	1	$3,899
Robokind R-25 ZENO Expressive Robot	ROBOKIND	2	$12,250
Laptops to interface with each humanoid	DELL	8	$12,229
First-year Engineering: Research and Design		**Project Total**	**$23,718**
Tetrix Base Education Set (item #5000446)	Pitsco & LegoEducation	12	
Tetrix Resource Set (item #5000455)	Pitsco & LegoEducation	12	
Lego EV3 Core Set (item #5003400)	Pitsco & LegoEducation	12	
Lego EV3 Expansion Set (item #45560)	Pitsco & LegoEducation	12	
Tetrix All Terrain Tire (item #5003366)	Pitsco & LegoEducation	48	
Tetrix Motor Encoder (item #5003342)	Pitsco & LegoEducation	48	
Tetrix DC Gear Motor (item #5003380)	Pitsco & LegoEducation	24	
Tetrix Rack and Pinion (item #5003367)	Pitsco & LegoEducation	12	
Tetrix Worm Gear Box 10:1 (item #5003368)	Pitsco & LegoEducation	12	
Tetrix Worm Gear Box 20:1 (item #5003368)	Pitsco & LegoEducation	12	
DC Motor Controller (item #5000490)	Pitsco & LegoEducation	12	
motor mounts stnd (item #5000461)	Pitsco & LegoEducation	12	
motor mounts non-stnd (item #5003369)	Pitsco & LegoEducation	12	
RobotC 30-seat license (item #5004125)	Pitsco & LegoEducation	1	
EV3 Software Site License (item #5003825)	Pitsco & LegoEducation	1	
Design and Fabrication		**Project Total**	**$73,456**
CNC Milling Machine	Tormach	1	$29,399
CNC Lathe system	Tormach	1	$24,399
Specialized components for above CNC systems	Tormach		$1,648
Pegasus 3D resin printer	Full Spectrum Laser	1	$3,300
System-30 (ABS/PLA) 3D printer by Hyrel	Hyrel, LLC	3	$14,710
Engineering & Design Software		**Project Total**	**$4,897**
25 seat MATLAB and Simulink Software	MathWorks	1	$6,937
Supplemental Department Funds			($2,040)
	Total Grant Expenditures - all projects		**$248,681**

III. Research Project Status/Summary

A. Project #1: Search-and-Rescue (Collaborators: Dr. Matt Nehring, Physics; and Professor George Sellman, Computer Science)

Description: Our goal is to develop a multi-robot system designed to carry out search-and-rescue missions in harsh environments including difficult terrain and unpleasant weather conditions. This project, new to Adams State, entails the use of two robots navigating rough four-wheel-drive roads, narrow trails used by off-highway-vehicles, and foot paths, while searching for a missing child or hiker. The robots must constantly communicate with one another and share information, but must also be in contact with a base. This is a complicated project of interest to many faculty in our department, and there are significant efforts being pursued around the country, albeit most similarly configured projects are related to robot-aided rescue after natural disasters. Given our isolated and rural geography, this project more readily addresses situations encountered in our environment and would be more likely to engage our students. Key components of the project involve the development and/or integration of algorithms for: navigating a trail or 4WD road; obstacle avoidance; extrication from problematic terrain; sampling; mapping; sharing of information directly between robots and to a common base-station.

Current Status: The Clearpath Robotics UGV systems were delivered to Adams State in June 2014. We are currently focusing our attention and efforts on *simultaneous localization and mapping* (SLAM) algorithms, obstacle avoidance, and communication between systems. To date we have had the systems roaming parts of campus but have not had the UGVs venturing in harsh terrain. This will come once we have more confidence in the navigation systems.

Additionally, we plan to incorporate some use of the UGV systems into our *First-year Engineering* course beginning Fall 2015 although we are still in the planning stages – details will develop during the summer months.

Finally, we plan to develop models of the UGV systems using the Simulink software purchased during the re-budgeting process. MATLAB will likely be used to develop and test many of the algorithms developed to operate on the UGVs.

B. Project #2: NAO Humanoid Robot (Collaborators: Dr. Matthew Iklé, Mathematics, and Professor George Sellman, Computer Science)

Description: The objective of this project is to expand current Adams State University research efforts in the area of artificial intelligence using the Aldebaran NAO robot platform (http://www.aldebaran-robotics.com/en/). These units are flexible systems that are sufficiently sophisticated for use as a robotics research platform while at the same time maintaining a suitably simple interface that can be used for undergraduate coursework or K-12 outreach efforts. Recent work by Dr. Iklé has included robot vision, object classification, facial expression and emotional recognition.

Additional directions planned for this research include the development of multi-robot teams designed to solve problems such as coordinated 3D mapping and localization, and other coordinated tasks such as playing soccer (a well-advertised and popular challenge).

As part of his on-going research, Dr. Iklé will involve students in the open-source artificial intelligence platform, OpenCog (http://opencog.org), using the NAO robots as the platform. The efforts of OpenCog are directed toward the development of an open source artificial intelligence framework. This effort will supply many exciting opportunities for undergraduate research projects in a wide range of mathematics, computer science, and engineering areas including topics in Bayesian statistics; probabilistic algorithms such as OpenCog's Probabilistic Logic Networks framework; modeling and simulation of large-scale systems; robotic sensors; and cognitive models of intelligence.

Current Status: Dr. Iklé is on sabbatical leave (Spring 2015) working on the above stated research program. He will return to Colorado in May 2015 and as usual he will spend much of his summer working on research. He is currently waiting to hear whether another grant proposal for an REU-type project at Adams State University will be funded. If it is, then several students will be recruited for the project.

MATLAB and Simulink have some support for the NAO robots and we expect students will naturally gravitate toward these powerful environments for the senior research projects.

C. Project #3: Visual Anonymity in Video Surveillance (Collaborators: Professor Ankur Chattopadhyay, Computer Science; Professor George Sellman, Computer Science; and Dr. Matt Nehring, Physics)

Current Status: As stated in Section I, Professor Chattopadhyay has left Adams State and therefore the equipment for this project was not purchased. We have no plans to research in this area at the present time.

D. Project #4: Colorado Robot Challenge (Collaborators: Dr. Matt Nehring, Physics; and Professor George Sellman, Computer Science)

Description: The goal of this project is to increase participation in the Colorado Robot Challenge (http://spacegrant.colorado.edu/statewideprograms/robotics-challenge and http://www.adams.edu/news/mar1023.php), an event organized and supported by the University of Colorado at Boulder through the Colorado Space Grant Consortium. Now in its tenth year, this event is scheduled for April 4, 2015 at Great Sand Dunes National Park, approximately a
45-minute drive from Adams State University. The aim of the Colorado Robot Challenge is to involve undergraduate students in the design of "small" autonomous robots (less than 1.5 kg) that can negotiate harsh terrain that approximates the terrain of Mars. Adams State University will be fielding two teams this year. Despite the fact the (ABS plastics) 3D

printers did not arrive on campus until January 2015, the groups participating in the Robot Challenge have designed and fabricated some specialized components for their robots using the Hyrel 3D printers.

Current Status: For the Colorado Robot Challenge as well as the *First-year Engineering* course, we plan to make use of the CNC milling machine and CNC lathe purchased as part of this grant. Both of these systems are complex machinery requiring long hours to assemble fully and subsequently test. Dr. Chris Adams from the Adams State Chemistry Program has been the driving force behind this effort. Both machines are now functioning and he is in the process of developing small "certification" projects that students must complete before they are allowed to use either system to fabricate their designs. Additionally, Dr. Adams will be teaching a course: "3D Printing and Fabrication" during Summer 2015. This will dramatically increase the number of students who are capable of using these machines to manufacture prototypes and/or one-off designs.

The *First-year Engineering* course will incorporate use of the TETRIX robotics systems beginning Fall 2015. With the expertise that students achieve with these systems during their course, they will be poised to design their own robotic systems for use in the Colorado Robot Challenge to be held in April 2016. The TETRIX systems allow for quick and sturdy designs to develop, while the CNC machines and 3D printers will complement their designs by providing a mechanism for incorporating custom components.

We have plans to incorporate Simulink into the *First-year Engineering* course as it has support for the Lego EV3 systems. We are currently evaluating the best development environment (LabView, RobotC, and Simulink).

E. Other Research (Collaborators: Dr. Chris Adams, Chemistry; Dr. Astalos, Physics; Dr. Nehring, Physics)

Finally, Dr. Chris Adams from the Chemistry Program has a student working on the design and development of a Stirling Engine, which the student is planning to construct using components fabricated on the CNC milling machine and printed with the ABS 3D printers.

MATLAB has already become popular with several faculty who have already taken steps to incorporating it into the curriculum (Dr. Astalos in PHYS 330 Numerical Methods and Dr. Nehring in CSCI 202 Programming for Science, Math, and Engineering). As faculty further recognize the power of this tool we anticipate making it significant component of several courses which in turn will enable students to incorporate the system into their senior research projects. Indeed, one student this spring has chosen MATLAB for his project that involves developing a mathematical model for a flag waving in the wind.

Summary Table Mapping Equipment to Research Projects

Clearpath Robotics UGV Mobile Research Platforms

Project #1: Search-and-Rescue
Project #4: Colorado Robot Challenge

NAO and ROBOKIND Humanoid Robot Systems

Project #2: NAO Humanoid Robot

TETRIX and Lego EV3 Robotics Systems

Project #4: Colorado Robot Challenge

Design and Fabrication

Project #1: Search-and-Rescue
Project #4: Colorado Robot Challenge
Other Research (Listed above as E)

MATLAB and Simulink Software

Project #1: Search-and-Rescue
Project #2: NAO Humanoid Robot
Project #4: Colorado Robot Challenge
Other Research (Listed above as E)

IV. Concluding Remarks

Three of the projects are proceeding as originally proposed and much of the equipment is already being used regularly. The effective lifetime for some equipment will be 5 years as technology changes rapidly in these areas (e.g. the NAO and ROBOKIND humanoids). For other systems, such as the CNC milling machine and the CNC lathe, the impact will extend beyond the careers of many faculty currently engaged in the work. Without external funding, none of these projects would be possible given the limited resources available to a small state-funded institution. We are grateful for the enhanced opportunities this grant will provide for our students.